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Large-scale Forcing of Late Summer Chlorophyll Blooms in the Oligotrophic Pacific

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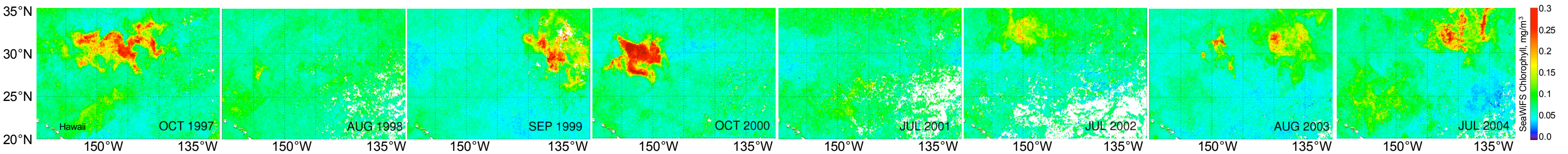
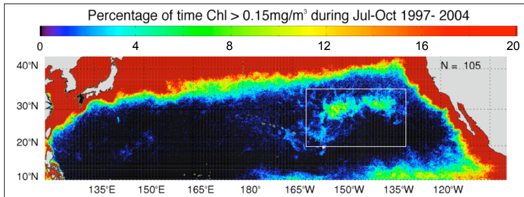
Summary

Large chlorophyll blooms observable with ocean color satellite data develop in late summer in the oligotrophic subtropical Pacific, northeast of Hawaii [*Wilson*, 2003]. The blooms are quite large, the largest ones reaching the size of California. They have been observed in 10 of 16 years of satellite ocean color data (CZCS, OCTS and SeaWiFS) and can last up to 4-5 months. The two most consistent aspects of the blooms are the timing of their development, occurring in late summer, and their location, centered along 30°N between 130-160°W. They do not appear to be caused by topographic features or by subsurface mixing. Nitrogen fixation and the vertical migration of *Rhizosolenia* diatom mats below the nutricline are two mechanisms that could bring new N into the surface ocean to fuel the blooms [*Wilson*, 2003]. Since cell buoyancy is crucial to either process, they do best under calm conditions, consistent with the timing of the chlorophyll blooms, which develop in late summer when wind speeds are lowest. Here we show that the location of the blooms is coincident with the highest abundances of *Rhizosolenia* diatom mats. The blooms also occur in the one region of the Pacific characterized by converging low surface currents, an environment that will allow buoyant organisms to congregate in large numbers at the surface *Yoder et al.* [1994].





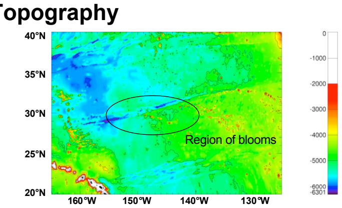
Bloom Characteristics

- Consistent location, appearing along 30°N and 130-160°W
- Consistent seasonality, developing in late summer, July-Sept.
- Significant interannual variability, occur in 10 out of 16 years of satellite ocean color data (CZCS, OCTS and SeaWiFS)

WHY???

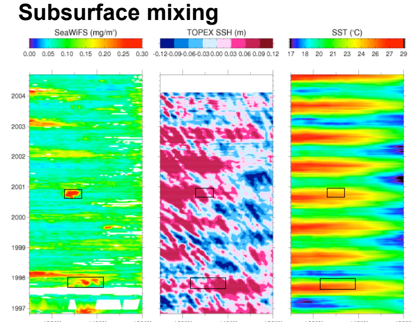
What *doesn't* appear to cause the blooms

Topography



Blooms occur in deep water, > 5000 m, with no nearby seamounts.

Subsurface mixing



Upwelling events that would bring subsurface nutrients into the surface are generally associated with negative SSH and SST anomalies; neither are observed coincident with the blooms.

What is unique to the region that could cause the blooms?

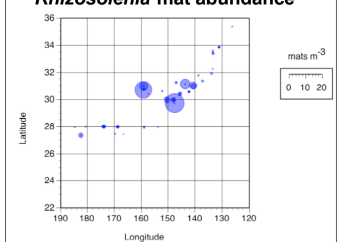
Biologically:

Nitrogen fixation is prevalent in the region by multiple organisms including *Trichodesimium* [*Karl et al.*, 1992], endosymbiotic cyanbacteria (*Richelia)* contained within *Hemialus* and *Rhizosolenia* diatoms [*Venrick et al.*, 1974; *Mague et al.*, 1974] and microbacteria [*Zehr et al.*, 2001], and could bring in new N to fuel the blooms.

Vertically migrating *Rhizosolenia* diatom mats have been extensively observed in this area [*Villareal & Carpenter*, 1989; *Villareal et al.*, 1996]. These mats migrate vertically below the nutricline and transport nitrate into the surface ocean. They occur in the highest abundance in the same region where the chlorophyll blooms are observed, 30°N and 140°-160°W (figure at right).

Since cell buoyancy is crucial to either process, they do best under calm conditions, consistent with the timing of the chlorophyll blooms, which develop in late summer when wind speeds are low.

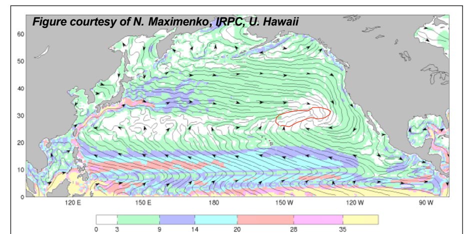
Rhizosolenia mat abundance



Spatial distribution of abundance of *Rhizosolenia* diatom mats in the N. Pacific. Data from *Aldredge & Silver* [1982], *Villareal & Carpenter* [1983], *Martinez* [1982] and unpublished datasets. Mat abundance was determined by divers *in-situ*. Methods are described in more detail in *Villareal et al.* [1996].

Physically:

The biological mechanisms that have been suggested as the cause of the blooms can explain the bloom's seasonality, but not their consistent location at 30°N, 130°-160°W, and their absence in the western part of the Pacific Ocean. This pattern suggests that the the blooms are driven in part by basin-scale physical forcing. The blooms occur in the one region of the Pacific characterized by both low surface currents and a convergence of currents [*Maximenko & Niiler*, 2004], an environment that will allow buoyant organisms, such as *Rhizosolenia* mats, to congregate in large numbers at the surface [*Yoder et al.* 1994].



Annual mean total currents (geostrophic + ekman) calculated between 1992-2002 by *Maximenko and Niiler* [2004]. Location of the blooms is outlined in red.

Future work

Analyze interannual variability in the convergence zone to see if it is consistent with the occurrence and location of the chlorophyll blooms.

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